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Original Manuscript

Depression mediates the relationship between alexithymia and obesity in the Northern Finland Birth Cohort 1966 (NFBC1966)

Running title: Alexithymia and depression effects on adiposity measures in the NFBC1966

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Abstract

Background: We recently reported a population-based analysis of the relationship between alexithymia and body mass index (BMI). Here, we explore the relationship between alexithymia and depression in relation to adiposity measures, including the direct and indirect effect of alexithymia and depression on obesity over a 15-year time-period, in the Northern Finland Birth Cohort 1966 (NFBC1966).

Methods: The study included individuals from the Northern Finland Birth Cohort 1966 (NFBC1966) who had available data for adiposity measures (body mass index and waist-to-hip ratio), alexithymia (measured by the 20-Item Toronto Alexithymia Scale: TAS-20), depressive symptoms (measured by the 13-item depression subscale of Hopkins Symptom Checklist: HSCL-13) at age of 31 years (n=4773) and 46 years (n=4431). Pearson's (r) correlation, and multiple linear regression were used to investigate the relationships between alexithymia, depression and adiposity measures. The potential mediating role of depression was examined *via* Hayes' procedure (PROCESS).

Results: Positive correlations were confirmed between adiposity measures (BMI and WHR) and the TAS-20 score (and its subscale), but not between obesity and HSCL-13 score. The strongest correlation was between the DIF (difficulty identifying feelings) subscale of the TAS-20 and HSCL-13 at both time points (31y: $r_{(3013)}$= 0.41, p<0.01, 46y: $r_{(3013)}$= 0.43, p<0.01). Depression completely (z=2.55 (±0.00003), p=0.01) and partly (z=2.16 (±0.0001), p=0.03) mediated the alexithymia-obesity relationship over the 15-year time-period.

Limitations: Other psychological and environmental factors such as interoception, dietary intake and physical activities may also play a role as a potential mediating factor in alexithymia-obesity relationship.

Conclusions: Our findings provide additional insights of theoretical framework of depression mediation effect in the relationship between alexithymia and obesity. Alexithymia and depression should, therefore, be considered in the design of future clinical obesity research.

Key words: Alexithymia, Depression, Mediation, Adiposity, Obesity, Body Mass Index, Waist-Hip Ratio

Introduction

There is a well-recognised relationship between emotional state and eating behavior, and we have previously reported that differences in people's ability to identify and express their emotions are corelated to body mass index (BMI) and its change over time in an unselected general population (Ramzi et al., 2018). Obesity develops through the consumption of more energy than is utilised, leading to a positive energy balance. This net over-consumption of energy can be attributed to a combination of genetics, environmental stimuli and, critically, the neuroendocrine system role in weight homeostasis and the development of obesity (Jastreboff et al., 2014; Zijlstra et al., 2012). Approximately 10% of the adult European population have a specific impairment in recognising, describing and distinguishing emotions – a construct known as alexithymia (Bird and Cook, 2013). The 20-item Toronto Alexithymia Scale (TAS-20) is commonly used to quantify this psychological trait (Bagby et al., 1994a, 1994b). It has been postulated that alexithymia leads to emotional eating among some obese individuals (Larsen et al., 2006; Pinaquy et al., 2003; van Strien and Ouwens, 2007). Alexithymia has been reported to be associated with depression (Hendryx et al., 1991; Honkalampi et al., 2000a) but there are inconsistencies in reports examining the relationship between severity of depression and TAS-20 score (Li et al., 2015). The direction of causality between alexithymia, depression and obesity is still undetermined.

The stability of alexithymia: it being an independent personality trait, as opposed to a state, has been debated for years. This controversy may stem from the concept of primary and secondary alexithymia introduced by (Freyberger, 1977). Primary alexithymia is suggested to be a personality trait, while secondary alexithymia results from trauma and stress, or even health problems, during adolescence or adulthood

(Lumley and Sielky, 2000). Alexithymia as measured by the TAS-20 is a multi-faceted construct encompassing deficits in emotional regulation and social-cognitive functioning. Thus, alexithymia has deficits in cognitive, physiological and behavioural mechanisms, according to the generally-accepted James Gross' models of emotion regulation (Gross, 2002, 1998).

Since alexithymia may be associated with depression (Markowitz et al., 2008), it is possible that the association of BMI with TAS-20 score in our previous study (Ramzi et al., 2018), may be mediated through depression. Here, we explore the relationship between alexithymia and depression, expanding this further to explain variance in adiposity measures. Based on the available evidence, we hypothesised that current depressive symptoms act as a mediating factor on the relationship between BMI and TAS-20 scores in the Northern Finland Birth Cohort 1966 (NFBC1966).

In our previous study of NFBC1966 (Ramzi et al., 2018), we noted that TAS-20 scores were not necessarily stable in individual people over a 15-year study period. It is possible that the observed differences in TAS-20 score reflect fluctuation in depressive symptoms in some individuals: alexithymia has been previously reported to be associated with depression (Hendryx et al., 1991; Honkalampi et al., 2000a), although the available data does not consistently show individuals with depressive symptoms scoring high in alexithymia (Li et al., 2015). The relationship may not be simple: it is possible that a disturbance in the cognitive appraisal of events and negative bias leads to a disturbance in emotions that may affect reporting of alexithymic tendencies (hwa Son et al., 2012). It has been suggested that there is an overlap, or a shared construct of emotional dysregulation between depression and alexithymia (Lumley, 2004). In this

study, we directly examine whether the observed differences in TAS-20 score in adults at the ages of 31 years and 46 years reflect differences in contemporaneous depressive symptoms as assessed by HSCL-13 score. Secondly, we evaluated whether there is inter-correlation between alexithymia, depressive symptoms and adiposity measures and whether change in TAS-20 and HSCL-13 scores relates to adiposity measures over time. Lastly, serial multivariate mediation pathways were tested to assess direct and indirect effects of alexithymia and depressive symptoms on adiposity outcome.

Materials and Methods

Study subjects and design

The data from individuals born in Northern Finland (Oulu and Lapland provinces) in 1966 is part of the NFBC1966 research program, which was designed to study the life-course epidemiology of the population (University of Oulu, 1966). In the current study, data at 31 years and 46 years' time points were included and as described previously (Nordström et al., 2021). In 1997 and 2012, detailed health and lifestyle postal questionnaires were sent to all individuals born in 1966, during which they were also invited to attend clinical examinations for a health check. The response rate for the 1997 postal questionnaires was 75% (N=8767) and for attendance at clinical examination was 71% (N=6033) of the eligible population (those still living in the original catchment area in Northern Finland and those who had moved to the capital city area, Helsinki and its surroundings). In 2012, the postal questionnaire was completed by 68.5% (N=6868) and clinical examination participation was 56.7% (N=5861). The study was approved by the Ethical committees of University of Oulu, Finland and the Northern Ostrobothnia Hospital District, Finland. Participants were included in this study if they had available anthropometric measures (and were not pregnant), and completed HSCL-

13, and TAS-20 scales at both the 31-year time-point (1997; n=4773) and the 46-year time-point (2012; n=4431).

Anthropometric, and socio-economic measurements

Heights and weights were collected from clinical examinations at 31-year and 46-year time points for all participants. Where information was available from both, there was no difference between measurements (self-reported and clinical examination) (Pearson's correlation r=0.98) for NFBC1966 at 31 and 46 years (data not shown). BMI (kg/m^2) for each participant was calculated by dividing weight (kg) by height^2 (m^2). BMI ranges were classified according to the WHO International Classification system which defines the following categories: underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese (≥30 kg/m^2) [20]. Waist-to-hip ratio (WHR) was also used as another measurement of obesity. WHR was recorded during the clinical examination at both time points and was calculated according to WHO guidelines ("Obesity: preventing and managing the global epidemic. Report of a WHO consultation.," 2000). Socio-economic variables considered in the analyses were marital status, education level, employment status and annual household income level. Detailed descriptions of the socio-economic status (SES) parameters in NFBC1966 have been reported previously (Ramzi et al., 2018).

Depression and alexithymia

Current depressive symptoms were assessed by the 25-item Hopkins Symptom Checklist (HSCL-25) questionnaire at the age of 31 and 46 years in the NFBC1966 participants. The HSCL-25 questionnaire contains the 13-item depression subscale (HSCL-13) and has been validated as a suitable instrument for psychiatric cases in the

Finnish population (Herva et al., 2006; Veijola et al., 2003). The current depressive symptoms score was generated by the sum of the HSCL-13 divided by the number of items answered from the HSCL-25 scale (Veijola et al., 2003). The severity of depressive symptoms was measured using a cut-off score of 1.75 which gave the same prevalence estimates as a diagnostic, clinical interview for depressive and anxiety disorders (Sandanger et al., 1999, 1998). Individuals with HSCL-13 score ≥ 1.75 were classified as depressed. ΔHSCL-13 score was calculated as $HSCL\text{-}13_{46y}$ - $HSCL\text{-}13_{31y}$. The 20-item Toronto Alexithymia Scale (TAS-20) (Bagby et al., 1994b, 1994a) was also undertaken at the participants 31st and 46th year of life. The reliability of this alexithymia measure in the Finnish population has been described by (Joukamaa et al., 2001). It has a three-factor structure; Difficulty Identifying Feelings (DIF), Difficulty Describing Feelings (DDF) and Externally Oriented Thinking (EOT). DIF is simply the inability to distinguish between emotional states or connect with one's own emotions. DDF is the inability to find the correct words for feelings (as the name alexithymia suggests) and EOT is the tendency towards a cognitive style that is oriented towards the external world rather than the inner self (Berardis et al., 2005). ΔTAS-20 score was calculated as $TAS\text{-}20_{46y}$ - $TAS\text{-}20_{31y}$.

Statistical analyses

For all analyses, the Statistical Package for Social Sciences (SPSS for Windows, version 24.0, 2004, Chicago, IL, USA) and PROCESS v3.3 (Hayes, 2018) were used. PROCESS is a macro for SPSS and was used to estimate direct and indirect effects of the mediation models. Mean effects and confidence intervals for scores on the HSCL-13 and TAS-20 were estimated applying Hayes' bootstrapping procedure with 5,000 resamples.

The prevalence rates of depressive symptoms at each time-point were analysed in relation to BMI. A paired t-test, stratified by sex, was used to explore how HSCL-13 scores had changed over the 15-years study period. Student's t-test (t) and ANCOVA were used to assess whether TAS-20 score differences in individuals reflected differences in concurrent depressive symptoms.

The Pearson's correlation coefficient (r) was used to assess correlations between HSCL-13 scores, TAS-20 scores (and subscales), and adiposity measures. The relative contribution of depression to the relationship between alexithymia and obesity was assessed using simple and multiple regression analyses, using the four-step method of testing for mediation, proposed by Baron and Kenny (Baron and Kenny, 1986). Predictors and outcomes in serial mediation models (including TAS-20 and its subscales, HSCL-13, BMI and WHR) were treated as continuous variables. Confounding variables (sex, marital status, educational level, occupation, and annual income) were controlled for in all models.

Results

Study sample characteristics

Of the NFBC1966 study sample, 4773 and 4431 participants completed HSCL-13, and TAS-20 questionnaires, and had available anthropometric (BMI and WHR), and socio-economic data, at both time-points. Mean HSCL-13, TAS-20 (and its subscales) scores and adiposity measures are shown in Table 1, along with SES data. In the whole group analysis, there was a significant difference in mean HSCL-13 score between the 31-year (M= 1.36, SD= ±0.36) and 46-year (M= 1.38, SD= ±0.41) time-points ($t_{(5773)}$=3.78, $p<0.0001$). Males showed an increase in mean HSCL-13 scores over the 15-year study

period (31y: 1.30±0.32, 46y: 1.35±0.40) ($t_{(2652)}$=6.14, p<0.0001), but there was no difference in females' scores.

As expected, the majority of the participants reported no depressive symptoms (HSCL-13 score) and were non-alexithymic (No $Depression_{31y}$: n= 4134, 86.6%; $Depression_{31y}$: n= 639, 13.4%; No $Alexithymia_{31y}$: n= 4457, 93.4%; $Alexithymia_{31y}$: n= 316, 6.6%; No $Depression_{46y}$: n= 4888, 83.7%; $Depression_{46y}$: n= 955, 16.3%; No $Alexithymia_{46y}$: n= 5065, 93.5%; $Alexithymia_{46y}$: n= 353, 6.5%). Statistically significant mean differences in the HSCL-13 score ($t_{(3784)}$=4.0, p< 0.001), DIF subscale ($t_{(3259)}$=2.19, p= 0.03), EOT subscale ($t_{(3259)}$=6.04, p< 0.001), BMI ($t_{(3894)}$=49.89, p< 0.001) and WHR ($t_{(3320)}$=54.11, p< 0.001) were observed between the two time points.

TAS-20 score was associated with concurrent depression status (by HSCL-13 score adjusted by sex, and socioeconomic status) at both 31 and 46 years of age, (both ages p<0.0001). TAS-20 scores were higher in the depressed group compared to the non-depressed group at both time points (mean differences: at 31 years, 5.55±0.43, at 46 years, 6.98±0.46), both p<0.0001). By the age of 46 years, individuals with current depressive symptoms had increased BMI by 1.15 kg/m^2 more than individuals without current depressive symptoms (p<0.0001).

Table 1 Demographic characteristics of selected variables at the two time-points (1997 and 2012) in the NFBC1966. Paired independent t-tests were used to measure mean difference in continuous variables over the 15-year time period.

Variables	31-year, 1997 (n=4773)	46-year, 2012 (n=4431)	Mean difference [95% CI]
Sex (Male/Female), n (%)	2240/533 (46.9/ 53.1)	1907/2524 (43/57)	
HSCL-13 (SD)	1.36 (0.36)	1.38 (0.41)	0.02 [0.01, 0.03]**
TAS-20 (SD)	43.93 (10.05)	44.12 (9.90)	0.19 [-0.10, 0.49]
DDF (SD)	10.83 (3.86)	10.79 (3.73)	-0.04 [-0.17, 0.08]
DIF (SD)	13.40 (4.65)	13.22 (4.61)	-0.18 [-0.33, -0.03]*
EOT (SD)	19.70 (4.61)	20.12 (4.30)	0.42 [0.27, 0.56]**
BMI (SD)	24.40 (4.00)	26.82(4.86)	2.42 [2.34, 2.50]**
WHR (SD)	0.85 (0.09)	0.92 (0.08)	0.06 [0.06, -0.07]**
Marital status, n (%)			
Married	2254 (47.4)	2687 (60.9)	
Cohabiting	1165 (24.5)	817 (18.5)	
Single	1142 (24.0)	482 (10.9)	
Divorced	189 (4.0)	410 (9.3)	
Widowed	3 (0.1)	18 (0.4)	
Education, n (%)			
1 - low	19 (0.4)	58 (1.3)	
2	2487 (52.1)	1401 (31.7)	
3	1752 (36.7)	993 (22.4)	
4 - high	511 (10.7)	1974 (44.6)	
Occupation, n (%)			
Employed	3308 (69.6)	3906 (89.9)	
Unemployed	802 (16.9)	225 (5.2)	
Others	642 (13.5)	216 (5.0)	
Income, n (%)			
1 - low	1103 (25.5)	876 (21.9)	
2	1181 (27.3)	1038 (25.9)	
3	994 (23.0)	916 (22.9)	
4 - high	1043 (24.1)	1177 (29.4)	

*p-value>0.05, **p-value>0.0001. HSCL-13: the 13-item depression subscale of Hopkins Symptom Checklist, TAS-20: the 20-item Toronto Alexithymia Scale, DDF: Difficulty Describing Feelings, DIF: Difficulty Identifying Feelings, EOT: Externally-Oriented Thinking, BMI: body mass index, WHR: waist-hip ratio. Educational level categories: i) no education or unfinished basic education, ii) completed 9-year basic education with or without vocational training or vocational school or post-secondary school, iii) completed 9-year basic education or matriculation examination with or without polytechnic education iv) completed 9-year basic education or matriculation examination with university degree. 'Others' employment status represents students, retired, and participants on paternity or maternity leave.

Inter-correlations between HSCL-13 scores, TAS-20 scores (and subscales), and adiposity measures

The results of the bivariate correlations are presented in Table 2. Positive correlations were found between HSCL-13 and TAS-20 scores at both timepoints ($r_{(3013)}$= 0.45-0.64, all p<0.01). The DIF subscale of TAS-20 showed relatively greater strength of correlation with HSCL-13 than the other subscales at both time points (31y: $r_{(3013)}$= 0.41, p<0.01, 46y: $r_{(3013)}$= 0.43, p<0.01).

Consistent with our previous findings, positive correlations were noted between BMI, and WHR ($r_{(3013)}$= 0.09-0.22, all p<0.01): these were also seen across all TAS-20 subscales. In addition, the TAS-20 scores between the time points showed a significant similarity ($r_{(3013)}$= 0.64, p<0.01).We then considered whether associations between current depression score and BMI or WHR were equally consistent. The alexithymia score showed stronger and more consistent associations with these measures of adiposity than did the HSCL-13 score.

The longitudinal relationship between ΔHSCL-13 and ΔTAS-20 was also investigated to determine the stability of both constructs in the NFBC1966. There was a positive correlation between ΔTAS-20 score and ΔHSCL-13 score in the longitudinal dataset ($r_{(3185)}$=0.19, p< 0.0001). Similar correlations were seen in males ($r_{(1690)}$=0.333, p< 0.0001) and in females ($r_{(2070)}$=0.276, p< 0.0001). In longitudinal analyses, a sex difference was observed in ΔHSCL-13 ($t_{(5772)}$= 4.41, p<0.001), but not in ΔTAS-20. The mean ΔHSCL-13 for males and females over the 15-year time-period was 0.05 (±0.39) and 0.006 (±0.43), respectively.

Table 2 Means, standard deviations and bivariate correlations among study variables at longitudinal level (n=3013).

Variables	Mean (SD)	Pearson Correlations												
		1	2	3	4	5	6	7	8	9	10	11	12	1
1. HSCL-13 $_{31y}$	1.34 (±0.35)	1												
2. HSCL-13 $_{46y}$	1.37 (±0.40)	0.45*	1											
3. TAS-20 $_{31y}$	44.0 (±10.03)	0.25*	0.22*	1										
4. TAS-20 $_{46y}$	44.08 (±9.85)	0.17*	0.31*	0.64*	1									
5. DDF $_{31y}$	10.84 (±3.85)	0.24*	0.20*	0.82*	0.54*	1								
6. DDF $_{46y}$	10.78 (±3.72)	0.17*	0.29*	0.54*	0.85*	0.58*	1							
7. DIF $_{31y}$	13.42 (±4.65)	0.41*	0.31*	0.78*	0.47*	0.57*	0.38*	1						
8. DIF $_{46y}$	13.20 (±4.58)	0.29*	0.43*	0.50*	0.81*	0.41*	0.64*	0.55*	1					
9. EOT $_{31y}$	19.73 (±4.60)	-0.07*	-0.01	0.70*	0.46*	0.37*	0.32*	0.22*	0.19*	1				
10. EOT $_{46y}$	20.10 (±4.30)	-0.06*	0.01	0.46*	0.70*	0.30*	0.39*	0.16*	0.24*	0.59*	1			
11. BMI $_{31y}$	24.42 (±4.07)	-0.02	0.03	0.09*	0.11*	0.05*	0.07*	0.03	0.09*	0.12*	0.09*	1		
12. BMI $_{46y}$	26.79 (±4.81)	0.03	0.09*	0.09*	0.10*	0.05*	0.05*	0.07*	0.10*	0.09*	0.08*	0.79*	1	
13. WHR $_{31y}$	0.85 (±0.09)	-0.09*	-0.02	0.17*	0.18*	0.14*	0.15*	-0.01	0.06*	0.27*	0.23*	0.50*	0.36*	1
14. WHR $_{46y}$	0.91 (±0.08)	-0.06*	0.02	0.21*	0.22*	0.17*	0.18*	0.02	0.08*	0.29*	0.27*	0.38*	0.44*	0

*Correlation is significant at the 0.01 level (2-tailed).

HSCL-13: the 13-item depression subscale of Hopkins Symptom Checklist, TAS-20: the 20-item Toronto Alexithymia Scale, DDF: Difficulty Describing Feelings, DIF: Difficulty Identifying Feelings, EOT: Externally-Oriented Thinking, BM

WHR: waist-hip ratio.

Statistically significant differences in mean ΔTAS-20 were observed between individuals with and without current depressive symptoms at both 31-year ($p= 0.007$) and 46-year ($p< 0.0001$) time points. Post-hoc analysis from the ANCOVAs revealed that NFBC1966 participants who had current depressive symptoms (HSCL-13≥ 1.75) at the age of 31 had lower mean ΔTAS-20, by 1.30±0.48 ($p=0.004$), than those without depressive symptoms. At the age of 46, participants who were experiencing current depressive symptoms had higher ΔTAS-20 by 1.88±0.44 mean difference compared to participants with no depression ($p< 0.0001$).

Serial mediation models

A series of exploratory serial multiple mediation models (24 models; Table 3) were investigated by four-step regression analysis to assess the possibility that depression might mediate the relationship between alexithymia and obesity. The standard, linear regression models performed were adjusted for covariates (sex, marital status, educational level, occupation and annual income).

Mediation analysis at the age of 31 years

Models 1-8 explored the relationships between measures and outcomes at age 31 years (1997 data). Model 1 confirmed a statistically significant direct effect of TAS-20 score on BMI (B= 0.0216, SE=0.0069, p=0.0016, CI= 0.0082-0.0351) at age of 31 years but there was no significant indirect effect *via* HSCL-13 score as mediator on BMI outcome at age of 31 years (B= -0.3530, SE=0.2134, p=0.092). A similar pattern was observed with WHR outcome at the age of 31 years (Model 5): there was a statistically significant direct effect of TAS-20 score on WHR (B= 0.0003, SE=0.0001, p=0.0047, CI= 0.0001-

0.0005) but no significant indirect effect was found *via* HSCL-13 score on WHR outcome (B= 0.008, SE=0.2134, p=0.533).

Analysis of the TAS-20 subscales (DDF, DIF, and EOT) was also conducted (Table 3). The EOT subscale at age of 31 years (Model 4 and Model 8) has a statistically significant direct effect on BMI (B= 0.0636, SE=0.0151, p< 0.0001, CI= 0.0340-0.0931) and WHR (B= 0.0012, SE=0.0002, p=0.0016, CI= 0.0007-0.0017): no significant indirect effect of mediation was seen in those models. Thus, the HSCL-13 score has no mediation effect on the relationship between alexithymia and obesity at age of 31 years.

Mediation analysis at the age of 46 years

A second set of models (9-16) explored the same relationships, in the same individuals, 15 years later, when the participants were 46 years of age in 2012. At this time-point, the TAS-20 score association with BMI was statistically significant (B= 0.0307, SE=0.0080, p=0.0001, CI= 0.0150-0.0463) in Model 9. Similar significant TAS-20 score and DIF subscale association with WHR at age of 46 years was seen in Model 13 (B= 0.0003, SE=0.0001, p=0.0008, CI= 0.0001-0.0005) and Model 15 (B= 0.0008, SE=0.0002, p=0.0003, CI= 0.0003-0.0012), respectively.

The results of the mediating effect are further confirmed by Sobel's test (Sobel, 1982) and partial mediation was found in Model 9 [z = 4.0395 (±0.0029), p = 0.00005], Model 13 [z = 3.2714 (±0.00003), p = 0.0010] and Model 15 [z = 2.985 (±0.0001), p = 0.0028]. Complete mediation of the relationship between alexithymia and obesity *via* depression was indicated in Model 11 (Table 3). Specifically, at the 46-year time-point, the DIF subscale association with BMI was statistically significant (B= 0.0611, SE=0.0165, p=0.0002, CI= 0.0288-0.0935). However, after including depressive symptoms as a

mediator in the equation model, the DIF subscale was no longer a significant predictor of obesity at age of 46 years, consistent with a complete mediation pathway (B= 0.0301, SE=0.0183, p=0.0988, CI= -0.0056-0.0659).

Mediation analysis over the 15-years study period (1997-2012)

Lastly, Models 17-24 were included to look at the data longitudinally, exploring how TAS-20 and HSCL-13 scores at the age of 31 years (1997) relate to change in adiposity over the 15-year study period. The TAS-20 score (B= 0.0003, SE=0.0001, p=0.0051, CI= 0.0001-0.0006) and its DIF subscale (B= 0.0008, SE=0.0002, p=0.0014, CI= 0.0003-0.0013) prediction on WHR at later age (46 years) was statistically significant in Model 21 and Model 23, respectively.

Model 21 revealed HSCL-13 score to be significant predictor of WHR at the age of 46 years (B= 0.0088, SE= 0.0034, p= 0.0096, CI= 0.0022-0.0155). The results of the mediating effect are further confirmed by Sobel's test (Sobel, 1982) and complete mediation was found in Model 21 [z= 2.5467 (±0.00003), p= 0.0109]. Model 23 revealed that both HSCL-13 (B= 0.0078, SE= 0.0036, p= 0.0282, CI= 0.0008-0.0148) and the TAS-20 DIF subscale at the age of 31 years (B= 0.0006, SE= 0.0003, p= 0.0363, CI= 0.0001-0.0011) were significant predictors of WHR 15 years later. The results of the mediating effect are further confirmed by Sobel's test (Sobel, 1982) and partial mediation was found in Model 23 [z= 2.1567 (±0.0001), p= 0.0310]. Similar to the mediation results at age of 46 years, depression mediated the alexithymia-obesity relationship over the 15-year time period.

Table 3 The serial mediation pathways tested. The bold text indicates models that reveal either complete or partial mediation effect of depressive symptoms on obesity in the NFBC1966.

Model	Pathway tested
1	31y: TAS-20 $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{31y}$
2	31y: DDF $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{31y}$
3	31y: DIF $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{31y}$
4	31y: EOT $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{31y}$
5	31y: TAS-20 $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{31y}$
6	31y: DDF $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{31y}$
7	31y: DIF $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{31y}$
8	31y: EOT $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{31y}$
9[#]	**46y: TAS-20 $_{46y}$ →HSCL-13 $_{46y}$ →BMI $_{46y}$**
10	46y: DDF $_{46y}$ →HSCL-13 $_{46y}$ →BMI $_{46y}$
11[*]	**46y: DIF $_{46y}$ →HSCL-13 $_{46y}$ →BMI $_{46y}$**
12	46y: EOT $_{46y}$ →HSCL-13 $_{46y}$ →BMI $_{46y}$
13[#]	**46y: TAS-20 $_{46y}$ →HSCL-13 $_{46y}$ →WHR $_{46y}$**
14	46y: DDF $_{46y}$ →HSCL-13 $_{46y}$ →WHR $_{46y}$
15[#]	**46y: DIF $_{46y}$ →HSCL-13 $_{46y}$ →WHR $_{46y}$**
16	46y: EOT $_{46y}$ →HSCL-13 $_{46y}$ →WHR $_{46y}$
17	TAS-20 $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{46y}$
18	DDF $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{46y}$
19	DIF $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{46y}$
20	EOT $_{31y}$ →HSCL-13 $_{31y}$ →BMI $_{46y}$
21[*]	**TAS-20 $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{46y}$**
22	DDF $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{46y}$
23[#]	**DIF $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{46y}$**
24	EOT $_{31y}$ →HSCL-13 $_{31y}$ →WHR $_{46y}$

[*] complete mediation effect

[#] partial mediation effect

HSCL-13: the 13-item depression subscale of Hopkins Symptom Checklist

TAS-20: the 20-item Toronto Alexithymia Scale

DDF: Difficulty Describing Feeling

DIF: Difficulty Identifying Feelings

EOT: Externally-Oriented Thinking

BMI: body mass index

WHR: waist-hip ratio

Discussion

The purpose of the present study was to investigate potential mediation of the relationship between alexithymia and obesity *via* depression. The results revealed a significant effect of HSCL-13 in mediating the relationship between alexithymia and obesity outcome at later age of 46 years and over the 15 years' period. DIF, as well as depressive symptoms at age of 31 years, predicted adiposity measures over the 15 years' period. Overall, our data indicate that alexithymia has both direct and indirect effects (*via* depression) on BMI in this cohort. Those people with high TAS-20 score particularly in DIF subscale and HSCL-13 score at age of 31 years were most likely also to have high BMI or WHR at later age (46 years). The TAS-20 score and its subscales; DIF and DDF were moderately related to depression severity. This finding confirms the conclusions of the Li et al., (2015) meta-analysis, which found the TAS-20 total score, DIF and DDF were moderately related to depression severity across different studies in clinical and general populations (Li et al., 2015).

Honkalampi et al., (2000) reported that depression has a strong relationship with alexithymia in the general population (Honkalampi et al., 2000a). Our study further confirms that alexithymia is associated with current depressive symptoms among adults in the general Finnish population. Previous findings suggest that alexithymia subscales (DIF, DDF and EOT) should be considered separately due to multi-dimensionality of the alexithymia construct (Goerlich, 2018; Hendryx et al., 1991). We found positive correlations between alexithymia (TAS-20 total score and its subscales) and depressive symptoms (HSCL-13), with higher strength of correlation seen between the DIF (difficulty identifying feelings) subscale and HCL-13 score. Our findings suggest a

greater role of difficulties in identifying and describing feelings/emotions (DDF and DIF) than action-oriented thinking (EOT) in obesity (de Zwaan et al., 1995; Leehr et al., 2015; Pinna et al., 2011; Zijlstra et al., 2012).

Earlier reports have suggested that age is strongly associated with alexithymia and depression in the general population (Fiske et al., 2003; Mattila et al., 2006; Salminen et al., 1999). Both alexithymia and depression appear to be more stable in older adults than in younger adults and adolescents (Fiske et al., 2009; Karukivi et al., 2014) suggesting age-related changes in both psychological constructs. As proposed by Murphy *et al*. (2017), alexithymia indicates the presence of poor interoception: the ability to perceive and construe bodily sensations (Murphy et al., 2018). In younger adults, evidence suggests a relationship between poor emotion recognition and both alexithymia and interoception (Cook et al., 2013; Terasawa et al., 2014). In the current study, the effect of alexithymia on adiposity was mediated *via* depression at the age of 46 years and over 15 years' period. These results suggest that the impact of interoceptive ability on obesity in the context of alexithymia and depression may alter across the lifespan.

There have been controversial debates over whether alexithymia is a stable trait (as a risk factor for depression) (Martínez-Sánchez et al., 1998; Saarijarvi et al., 2002; Schmidt et al., 1993) or a state (as a defensive consequence of depression) (Hendryx et al., 1991; Honkalampi et al., 2000b). In addition, it has been suggested that there is an overlap, or a shared construct of emotional dysregulation between depression and alexithymia (Lumley, 2004). From our findings, alexithymia appears to be a stable trait based on the similarity of the mean TAS-20 scores over 15 years' period. It has been

suggested that in severely obese patients, the alexithymia construct might reflect an underlying eating disorder, such as binge eating disorder (BED), and chronic obesity could result in an individual being prone to secondary (state) alexithymia (Lumley et al., 2007). A previous longitudinal study of the NFBC1966, using data from the 14-year and 31-year time points showed that adolescent obesity was associated with depressive symptoms at the age of 31 years (Herva et al., 2006). In addition, male abdominal obesity was associated with a higher life-time risk of clinical depression and with experience of current depressive symptoms at time of survey (Herva et al., 2006). Emotional inhibition strategies may be used as coping mechanisms by people with depression, leading to a higher prevalence rate of alexithymia among these patients, as compared to the general population (hwa Son et al., 2012).

The cross-sectional and longitudinal designs of a non-selected general population add strength to our study, which further underpins the theoretical models of obesity and psychological factors in the literature. Potential imitations include the fact that although exploration of depression as a potential mediating factor was chosen and guided by previous literature, due to co-morbidity it is possible that other psychological and environmental factors may also play a role. Furthermore, lifestyle and environmental exposures may also confound the relationships between obesity, depression, and alexithymia that we observed in this study. Interoception has been associated with alexithymia (Brewer et al., 2016), and failure to perceive and correctly interpret bodily sensations may also be an important mediating factor in the relationship between alexithymia and obesity: our current dataset does not allow exploration of this matter. The assessment tools used may also be an important factor: self-report tools (for e.g. TAS-20, Beck Depression Index, HSCL-25) have stronger inter-correlations. Observer-

led depression scales (such as the Hamilton Rating Scale for Depression) appear to exhibit weaker correlations with alexithymia, indicating that there may be some self-report bias in the data (Li et al., 2015).

A range of theories of eating behaviour, such as psychosomatic, external eating, and restraint hypotheses have been posited to understand the role of emotion regulation in obesity and/or eating disorders (Canetti et al., 2002). However, the exact mechanism by which emotions affect eating behaviours and/or obesity, remains unknown. In addition, the exact roles of psychological disorders, anxiety, and depressive symptoms in the aetiology of obesity are equally elusive. Alexithymia may provide insight into the process of emotion regulation differences in individuals with obesity or at risk of developing it. Several theories have been offered to explain the associations between alexithymia, anxiety, depression and emotional eating. In line with previous debates on alexithymia stability, alexithymia could be a primary (personality) or secondary (or state) trait connected to some cases of obesity. If alexithymia is a personality/primary trait for some people with obesity, other risk exposures (genetic and/or environmental), anxiety and depression could be acting as mediators for emotional eating, which could increase their food consumption and lead to obesity. As such, therapeutic approaches to achieve durable weight-loss may need to consider alexithymia as a potential factor to be addressed.

Conclusions

Here we report an exploration of the relationship between alexithymia, depression and obesity in a European birth cohort, over a 15-year study period. The data suggest that alexithymia (as assessed by TAS-20) has both indirect and direct effects on adiposity

measures (BMI and WHR). Mediation analysis suggests that the effect of total TAS-20 score, and specifically its DIF subscale, on adiposity is mediated through depression in a population sample.

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Data availability

NFBC data is available from the University of Oulu, Infrastructure for Population Studies. Permission to use the data can be applied for research purposes via electronic material request portal. In the use of data, we follow the EU general data protection

regulation (679/2016) and Finnish Data Protection Act. The use of personal data is based on cohort participant's written informed consent at his/her latest follow-up study, which may cause limitations to its use. Please contact NFBC project center (NFBCprojectcenter(at)oulu.fi) and visit the cohort website for more information.

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